



WILLIAM & MARY
CHARTERED 1693

W&M ScholarWorks

Reports

12-1-1995

Water!

Kirk J. Havens

Virginia Institute of Marine Science

Virginia Institute of Marine Science, Wetlands Program

Follow this and additional works at: <https://scholarworks.wm.edu/reports>



Part of the [Natural Resources and Conservation Commons](#)

Recommended Citation

Havens, K. J., & Virginia Institute of Marine Science, Wetlands Program. (1995) Water!. Wetlands Program Technical Report no. 95-7. Virginia Institute of Marine Science, College of William and Mary.
<http://dx.doi.org/doi:10.21220/m2-3j8c-8v50>

This Report is brought to you for free and open access by W&M ScholarWorks. It has been accepted for inclusion in Reports by an authorized administrator of W&M ScholarWorks. For more information, please contact scholarworks@wm.edu.



Wetlands

Program



Technical Report

December 1995

No. 95-7

Water!

Kirk J. Havens

Water. H_2O . A simple combination of hydrogen and oxygen, but it serves as the base of life on Earth. A person requires approximately 3 quarts of potable water per day to maintain essential body fluids. The typical American uses 50 to 60 gallons per day and a single toilet flush may use 6 gallons (Fetter, 1988). For contrast, primitive people in desert lands exist with 3 quarts as their total daily allotment of water.

The largest movement of a chemical substance at the surface of the Earth is the annual circulation of water. Heat from the sun evaporates pure water from the surface of the Earth but mostly from the oceans. The water vapor is lifted to

higher elevations where it moves through the atmosphere until condensing and falling as precipitation in a process we call "weather." But how and when did water first appear on Earth?

To answer that we must glance (yes it is quite a glance indeed) back in time to the origin of the solar system. The planets in our solar system formed from the coalescing of small bodies called planetismals (Press and Siever, 1986) and the accretion of the Earth was completed about 3.8 billion years ago. We now know that almost all of the water present today can be accounted for from the water vapor delivered to the Earth by comets and the subsequent volcanic degassing (Chyba, 1987). Once the Earth's surface cooled to $100^{\circ}C$ water condensed out of the primitive atmosphere and formed the oceans about 3.8 billion years ago (Holland, 1984).

It is believed that the present volume of water is close to that of primitive Earth. Most of our water supply is, of course, found in the saline oceans and over 75% of the water in

Athabasca River in the Canadian Rockies.



Photo by Kirk Havens

land areas is locked in glacial ice (Figure 1, see pg. 3). Only a small fraction is available to us as fresh water and more than 98% of fresh water is ground water. Water vapor in the Earth's atmosphere represents only 0.001% of the total water supply. Although it is a small fraction of the total, the rapid recycling of atmospheric water vapor exerts enormous control over our climate.

When discussing water it is convenient to talk of hydrologic cycles and budgets. Hydrologic cycles depict the pathways of water through a system while a hydrologic budget attempts to assign a number to the fluxes and pools of water. A hydrologic cycle can show the flow of water on a global scale or on a scale as small as a backyard pond and the same is true for budgets (Figure 2, see page 4).

The main components of the hydrologic cycle are: 1) clouds and radiation; 2) atmospheric moisture; 3) precipitation; 4) ocean fluxes; and 5) land surface processes (Chahine, 1992).

Wetlands Program
School of Marine Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

Dr. Carl Hershner, Program Director
Publisher by: VIMS Publication Center

This technical report was funded, in part, by the Department of Environmental Quality's Coastal Resources Management Program through Grant #NA47OZ0287-01 of the National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resources Management, under the Coastal Zone Management Act of 1972, as amended.



Commonwealth's Declared Policy:
"to preserve the wetlands and to prevent their
despoliation and destruction..."

Printed on recycled paper. 

The sun's radiation is dominated by short wavelengths which are absorbed or reflected by the Earth's surface. "Greenhouse" gases, such as CO₂, CH₄, and chlorofluorocarbons, absorb reflected long wavelength radiation and an increase in these gases could result in a warming of the Earth. Clouds act as both scatterers and absorbers of radiation by reflecting incoming solar radiation and by trapping outgoing radiation. Simply stated, if clouds reflect more radiation then they trap then a cooling of the Earth's surface may occur. If however, the clouds trap more emitted radiation then a surface warming may result (Rind et al., 1991). The net effect depends on cloud microphysical characteristics (cloud droplet size), vertical and horizontal extent, and atmospheric interaction (Chahine, 1992).

Atmospheric moisture, we know, circulates very rapidly with a global residence time of about 10 days (Figure 2) and each year enough water falls on the United States (excluding Alaska) to cover the lower 48 states to a depth of 75 cm. Of this amount, 55 cm are returned to the atmosphere through evaporation and transpiration by plants and 20 cm flow into the oceans as rivers (Hendricks and Hansen, 1962). Precipitation is highly variable with 2/3 of global precipitation occurring between latitudes 30°N and 30°S (Chahine, 1992). This variability has enormous influence on vegetation, droughts, and floods and affects the large scale circulation of the atmosphere and oceans. There is a strong interaction between the ocean and the atmosphere which is controlled primarily by sea surface temperature, precipitation, and wind stress. Changes in sea surface temperature, influenced by the surface winds and precipitation, can change ocean upwelling and current systems. This interactive feedback loop is evident in the El Niño/Southern Oscillation phenomena in the Pacific Ocean. During normal conditions (La Niña), currents driven by the trade winds carry warm surface waters to the western Pacific, allowing the cold, nutrient rich, bottom waters to upwell along the Peruvian coast. At a cycle of between 3 and 5 years, this surface transport breaks down and the warm surface waters remain along the coast, preventing the upwelling (El Niño). This lack of nutrient rich water limits phytoplankton growth and fish

populations (anchovies) dependent on abundant phytoplankton collapse (Philander, 1989).

Oceans contribute to the global hydrologic cycle by storing heat and releasing water vapor and by transporting heat from the subtropics poleward. This system can be visualized as similar to a house heating system that moves heat from a central furnace to cooler rooms. Disruptions in this flow of heat can lead to vastly different circulation patterns. For example, as the warm surface waters of the Atlantic move northward they sink due to increased salinity and cooling and then flow south. However, with the addition of fresh water by the melting of the ice caps, for example, the density of the upper ocean layer is reduced and sinking is repressed. This would create a cap over the ocean waters affecting the transport of heat to the higher latitudes (Chahine, 1992).

Evaporation of soil water and transpiration by plants are major components of the hydrologic cycle on land. The solar energy absorbed by the Earth's surface is dependent on surface albedo (reflectivity) which in turn, is determined by snow and ice cover, vegetation and bare soil conditions. Vegetation complicates the issue since plant transpiration is determined by the morphology and physiology of the plant species.

Many complicated, intertwined components are involved in the cycle of water through our environment and actually quantifying the fluxes and pools is very difficult. Equations and budgets have been developed in an attempt to unravel the mystery of water movement. A hydrologic equation is a simple statement of the Law of Mass Conservation and is expressed as:

$$\text{Inflow} = \text{Outflow} \pm \text{Changes in Storage}$$

While this may appear simple enough, the calculation of the inflows and outflows is extremely complicated. Let's take the hydrologic budget expressed as:

$$V/t = P_n + S_i + G_i - ET - S_o - G_o$$

where:

- V = Volume of water
- V/t = Change in volume per unit time
- P_n = Net precipitation
- S_i = Surface inflows (stream, etc.)
- G_i = Groundwater inflows
- ET = Evapotranspiration
- S_o = Surface outflows
- G_o = Groundwater outflows

Now if we look at just one of these terms, say P_n , we see how complicated this can get. Precipitation should be simple enough to quantify, but is it really? During a rain event some rain is intercepted by vegetation before it reaches the ground and is termed interception. In heavily forested areas the storage capacity of the leaf surfaces may be sufficient to retain most of the rain and it may evaporate with very little reaching the forest floor. The rain that does reach the forest floor is

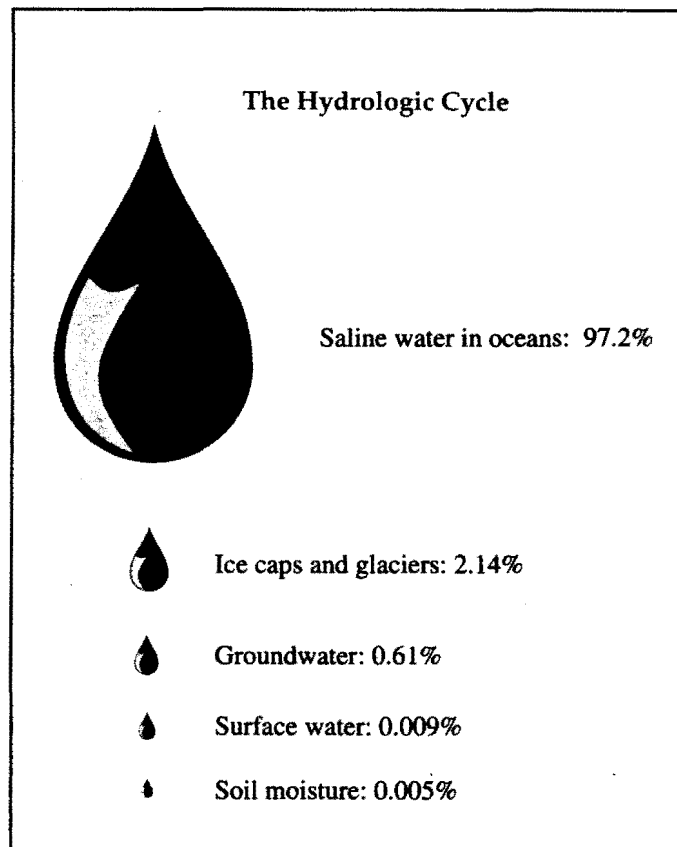
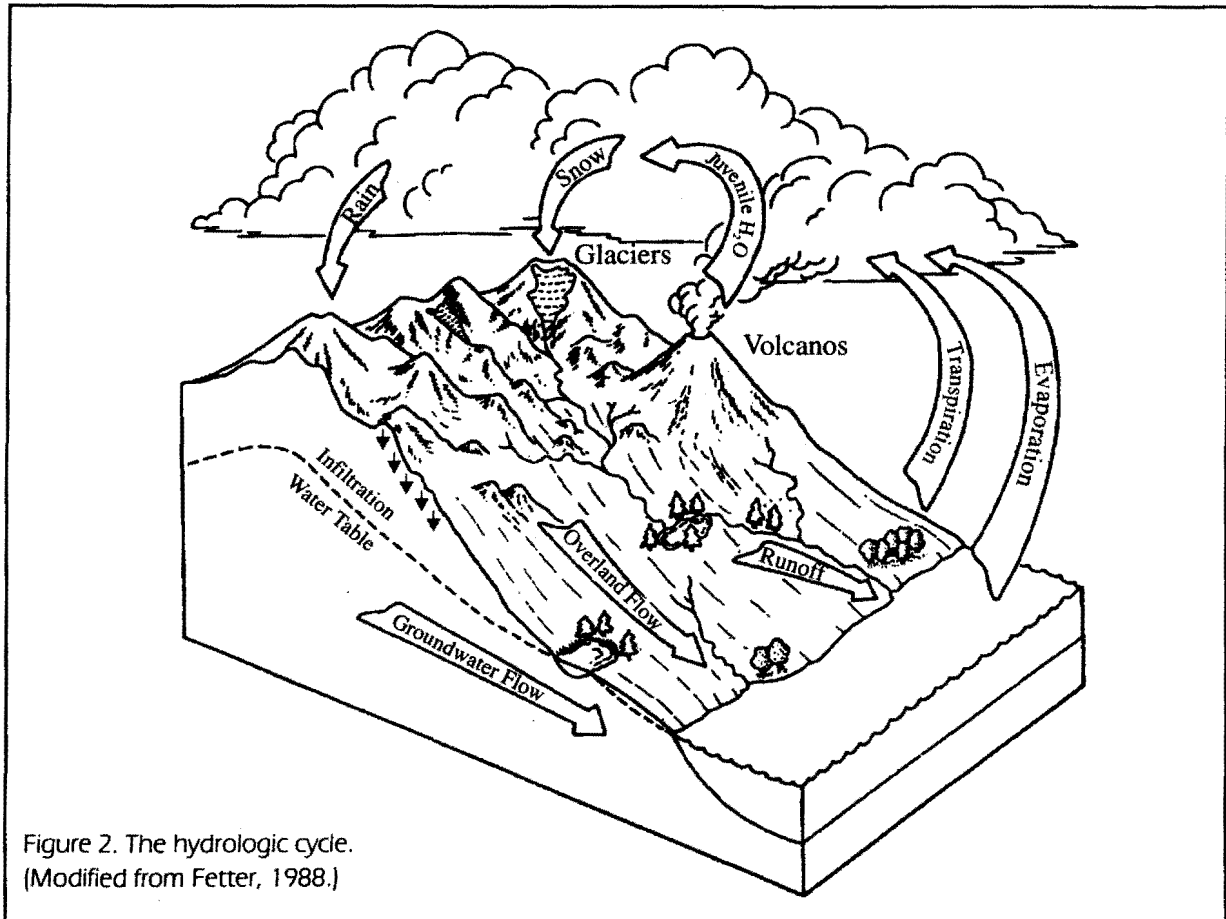


Figure 1. Distribution of the world's water supply. (Modified from Fetter, 1988.)



called throughfall. In addition, if the storage capacity of the leaf surfaces is exhausted then the rainfall may run down the tree trunks (stem flow). So our term P_n is now represented by the equation:

$$P = I + TF + SF$$

where:

- P = Total precipitation
- I = Interception
- TF = Throughfall
- SF = Stemflow

and P_n (the total amount of water reaching the surface) is:

$$P_n = P - I \text{ or } P_n = TF + SF$$

Numerous methods are utilized in an attempt to quantify the above terms and each has its benefits and detriments. For example, one method for measuring free water evaporation for use in quantifying water loss due to evaporation from water surfaces such as lakes and reservoirs is the land pan. Land pans are standardized, shallow pans placed on supports so that air can be circulated all around. Records are kept of the daily depth of water, the daily precipitation into the pan, and the volume of water added to replace the evaporated water. Errors can occur from splash caused by heavy rainfall and drinking by birds. In addition, a pan will warm much more quickly than a lake or reservoir and wind speed can affect evaporation rates. And consider, evaporation is one of the easier terms to quantify.

Glacier in the
Canadian Rockies.



Photo by Kirk Havens

Now look at the calculation for evapotranspiration using the Penman Equation (Chow, 1969):

$$ET = \frac{H + 0.27E_a}{+ 0.27}$$

where:

ET = Evapotranspiration in mm/day
= Slope of curve of saturation vapor pressure vs. mean air temperature in mmHg/°C

H = Net radiation,
cal/cm²-day = $R_t(1-a) - R_b$
R_t = total shortwave radiation
a = albedo of surface
R_b = effective outgoing long
wave radiation = $f(T^4)$

E_a = Term describing the contribution of
mass-transfer to evaporation =
 $0.35 (0.5 + 0.00625u)(e_w - e_a)$

u = wind speed 2 m above ground in
km/day

e_w = saturation vapor pressure of water
surface at mean air temperature in
mmHg

e_a = vapor pressure in surrounding air
in mmHg

As complicated as the foregoing may seem, calculating groundwater interaction is far more difficult. However, an understanding of groundwater fluctuations and flows is essential in understanding natural systems such as wetlands, which are driven by these interactions. Indeed, federal jurisdiction governing activities within these systems is determined, in part, by the frequency and duration of water. In many cases the fluctuation of the groundwater level is not easily observed since much interaction occurs within the root zone (top 15cm of the soil profile) and the presence of standing water is infrequent. Figures 3 and 4 show the significant amount of groundwater activity just below the soil surface in a site dominated by cedar trees and maple-gum trees, respectively.

The ability to model water budgets becomes increasingly important as resource managers look to constructing wetlands as a means to replace lost natural wetlands. Establishing the proper hydrologic conditions when constructing a wetland is paramount and, as noted earlier, this can be an intricate, tedious, and expensive process.

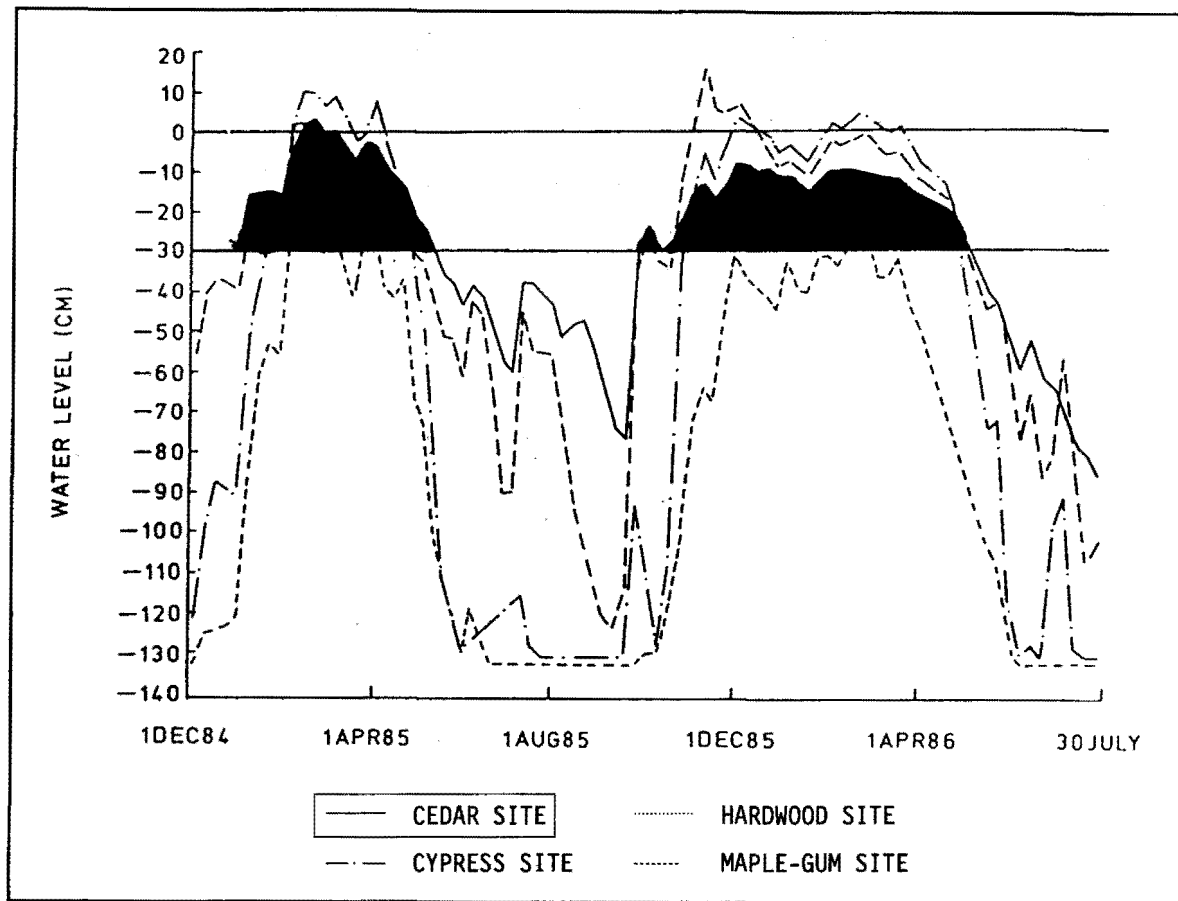


Figure 3. Cedar tree site (shaded). Top horizontal line indicates soil surface; lower horizontal line indicates bottom of root zone. (Modified from Day et al., 1988)

ture. Problems with hydrologic budget models are amplified when the maturation of the constructed system is considered. For example, a detailed knowledge of the transpiration rate of certain tree species would be necessary if seedlings are planted in a constructed site. As the system matures the transpiration rate (and the drawdown of the water table) will change with tree growth. Presently, information on the transpiration rates of various trees of different ages is generally lacking. At stake, however, is our wetland resource which will be significantly reduced if natural wetlands are lost and our constructed wetlands eventually fail.

In short, establishing accurate hydrologic budgets is highly complex and much work continues to be done on refining measurement techniques.

Water is fundamental to life on Earth. Coupled with the sun's energy it determines the Earth's climate and distinguishes the Earth from its sister planets. The presence of water within our landscape forms wetlands which are considered some of the most productive areas for wildlife. This intricate balance between water loss and water gain allows these wetland systems to persist which, in turn, provides a constant or recurrent habitat for a myriad of wildlife. The fate of water will determine the fate of life on Earth and continued research into the dynamics of this essential elixir of life will lead to a better understanding of this most precious resource.

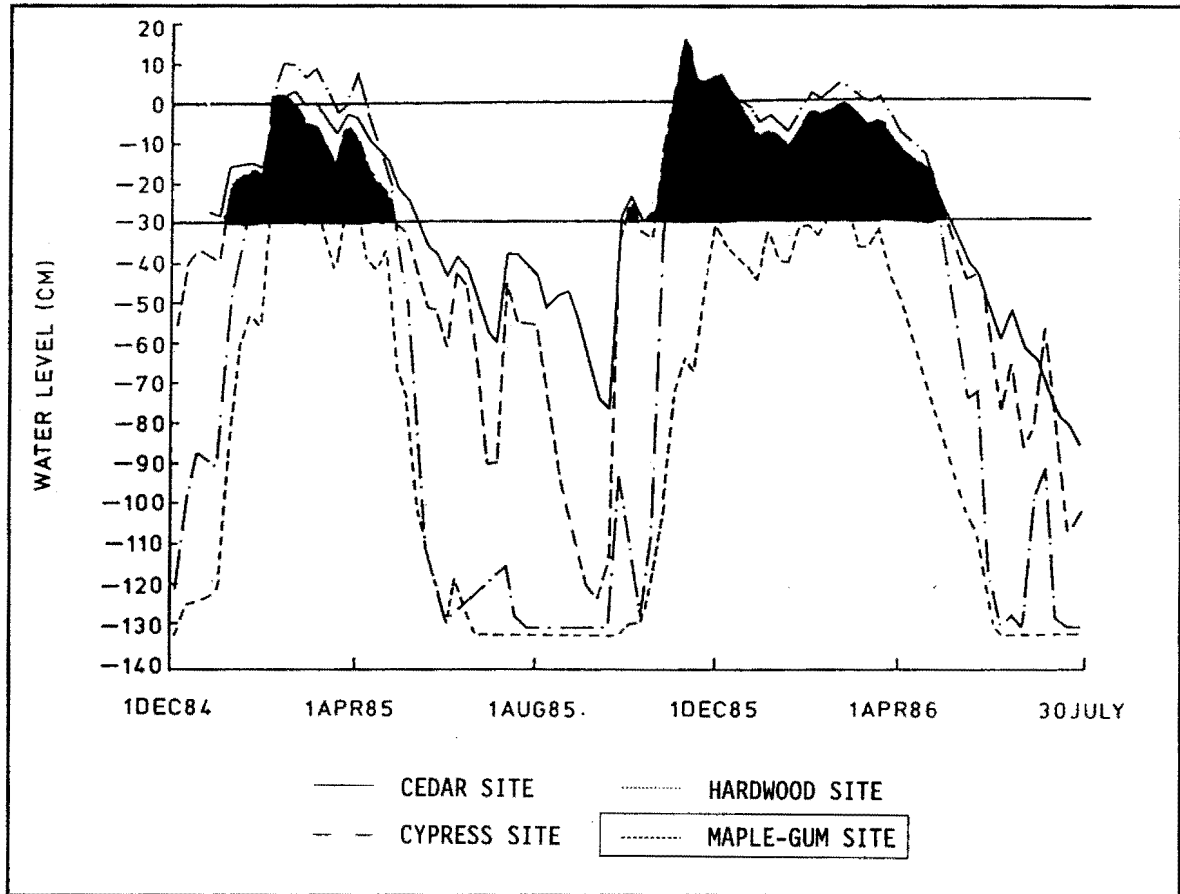


Figure 4. Maple-gum tree site (shaded). Top horizontal line indicates soil surface; lower horizontal line indicates bottom of root zone. (Modified from Day et al., 1988)

Literature Cited

- Chahine, M.T. 1992. The hydrologic cycle and its influence on climate. *Nature* 359: 373-380.
- Chyba, C.F. 1987. Cometary contribution to oceans of primitive Earth. *Nature* 330: 632-636.
- Day, F.P., S.K. West and E.G. Tupacz. 1988. The influence of ground-water dynamics in a periodically flooded ecosystem, the Great Dismal Swamp. *Wetland* 8:1-14.
- Fetter, C.W. 1988. *Applied Hydrogeology*. Macmillan Publishing Co., New York, New York, 592pp.
- Hendricks S. and L. Hansen. 1962. Federal Council for Science and Technology, *Scientific Hydrology*. Washington, D.C. U.S. Government Printing Office.
- Holland, H.D. 1984. *The Chemical Evolution of the Atmosphere and Oceans*. Princeton University Press, Princeton.
- Press, F. and R. Siever. 1986. *Earth*, 4th ed. W.H. Freeman, New York.
- Rind et al. 1991. *Nature* 349: 500-503.
- Philander, G. 1989. El Niño and La Niña. *American Scientist* 77: 451-459.



Wetlands Program
School of Marine Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062
ADDRESS CORRECTION REQUESTED

NONPROFIT
ORGANIZATION
U.S. POSTAGE PAID
GLOU. PT. VA 23062
PERMIT NO. 6
